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ABSTRACT

This packet of space science instructional materials includes five issues related to the planet Jupiter. Each issue presents factual material about the planet, diagrammatic representations of its movements and positions relative to bright stars or the earth, actual photographs and/or tables of data collected relevant to Pioneer 10, the spacecraft whose target is Jupiter. Issue No. 1 describes the relationship of Jupiter to the other planets. The physical characteristics of Jupiter are discussed in the second issue. Jupiter and Earth are compared, with emphasis on the evolution of planets, in Issue No. 3. Issue No. 4 describes Pioneer 10's mission to Jupiter and Issue No. 5, Pioneer's encounter with Jupiter. In each issue, student study projects are presented, and a few suggested readings are listed. (EB)

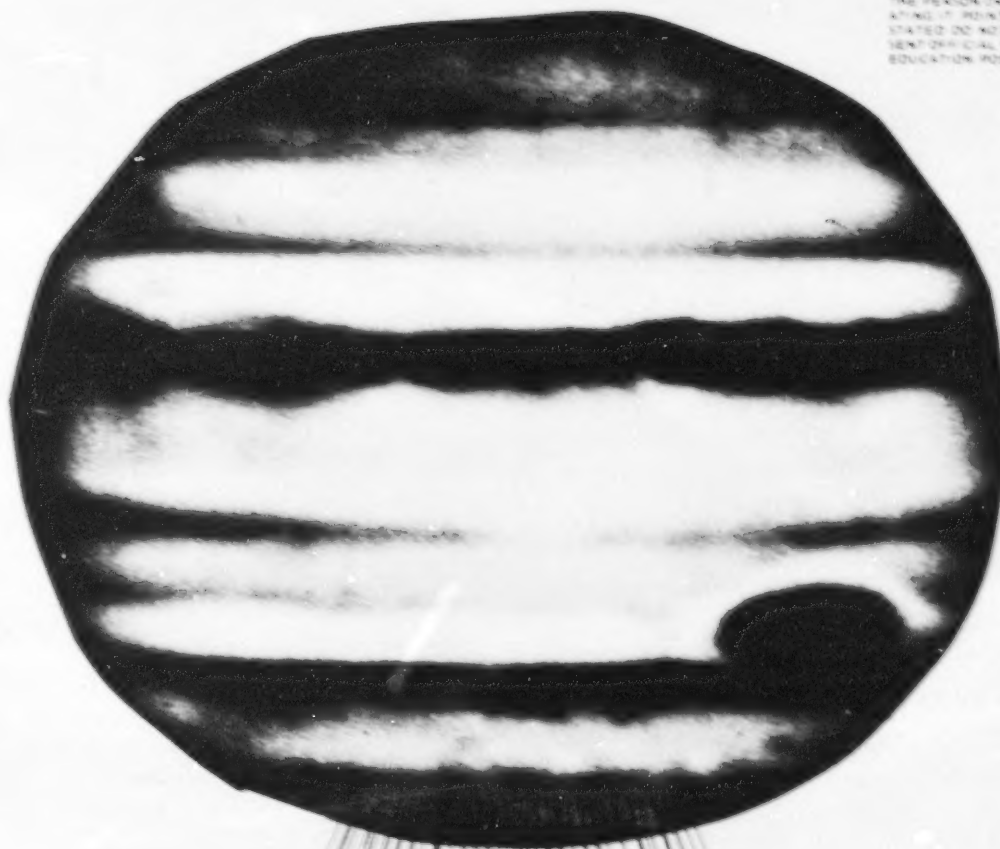
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THE NOW FRONTIER

MAN LINKS EARTH AND PLANETS PIONEER TO JUPITER

U.S. DEPARTMENT OF HEALTH,
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ISSUE NUMBER ONE

SE 017 037

JUPITER...GIANT OF THE SOLAR SYSTEM

RELATIONSHIP OF JUPITER TO THE OTHER PLANETS

Orbiting at a distance of 485 million miles, Jupiter is some four and a half times as distant from the Sun—the center of the Solar System—as is Earth. And Jupiter is 350 million miles beyond the orbit of Mars, the most distant planet previously reached by spacecraft from Earth.

Jupiter is the target of two Pioneer spacecraft, the first of which, Pioneer 10, is due to arrive and fly close by the planet early in December, 1973.

In Roman and Greek mythology, Jupiter was the name of the most powerful and capricious ruler of the heavens. Small wonder that ancient astronomers gave the same name to the planet that is the brilliant ruler of the night sky year after year. Today, astronomers acknowledge Jupiter as perhaps the most important planet of the Solar System, certainly the largest and most massive. Indeed, the Solar System has been referred to as the Sun and Jupiter plus a lot of debris because after the Sun, Jupiter contains two-thirds of all the matter in the Solar System.

Planets of the Solar System consist of two distinct types: small, dense inner planets with solid surfaces—Mercury, Venus, Earth and its Moon, and Mars—and large, predominantly gaseous outer planets—Jupiter, Saturn, Uranus and Neptune. Pluto, the outermost known planet, cannot be observed well enough to be accurately classified though it is believed to be similar to the inner planets. Also, between the orbits of Mars and Jupiter is a zone of minor planets called asteroids, the largest of which, Ceres, is only 500 miles in diameter while most are much smaller.

In distance outwards from the Sun, the asteroids represent the end of the inner planets while Jupiter is the first of the outer planets.

DOMINANT POSITION

Jupiter is an unusual planet by earthly standards. Only slightly denser than water, the planet would almost float. Yet Jupiter is 318 times more massive than Earth. Because of its great mass Jupiter dominates the Solar System, secondary only to the Sun itself. Its gravity affects the orbits of the other planets and may have prevented the asteroids from falling together to become a planet. The orbits of many comets, too, are affected by Jupiter. Some have been captured and are now under control of the big planet.

Jupiter is close to being a second Sun; it is just slightly too small for its own weight to raise its central temperature high enough for nuclear fire to be ignited in its core. Had Jupiter been slightly larger the Solar System could have been a binary star system and nighttime would have occurred rarely on

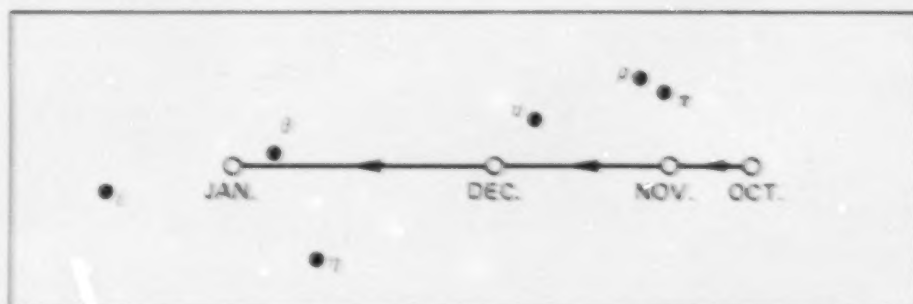


Figure 1. Movement of Jupiter Against Stars of Capricornus

Earth. As it is, Jupiter emits more energy into space than it receives from the Sun.

FAMILY OF SATELLITES

Galileo discovered four satellites of Jupiter in 1610 when he first looked at the planet with the newly invented telescope. Two of these satellites, Callisto and Ganymede, are about the size of the planet Mercury, while Io and Europa rival Earth's Moon. You can easily see these big satellites through a pair of field glasses. They range in an almost straight line on either side of Jupiter as star-like objects. Watched night after night they change their positions as they follow orbits around Jupiter. Romer measured the finite speed of light (186,000 miles, or seven times around the Earth, per second) over astronomical distances by observing the motions of these satellites.

Today, Jupiter is known to have at least twelve satellites—the other eight are much smaller bodies. The Jovian system thus resembles a miniature Solar System, except that some satellites of Jupiter orbit oppositely to others, whereas all the planets go around the Sun in one direction.

SOLAR ORBIT AND APPEARANCE OF JUPITER IN THE SKY (APPARITIONS)

It is instructive to look at Jupiter from the standpoint of the early astronomers. Earth bound, they watched the motions of the planets against the background of stars and deduced that the planets including the Earth move around the Sun in almost circular orbits. Because Jupiter orbits the Sun outside the orbit of the Earth, Jupiter is called a superior planet. As seen from Earth, superior planets appear to move close to the ecliptic (the apparent yearly path of the Sun relative to the stars, which is the plane of the Earth's equator projected against the stars), and to move eastward all the way around the sky as they travel on their solar orbit. Jupiter takes 11.8 Earth years to travel completely around the Sun; thus, it also takes almost 12 years to move around the star sphere. Jupiter moves along the ecliptic year by year progressively entering each of the Zodiacal constellations. This year (1973) Jupiter is in the western part of Capricornus (The Goat). Next year it will have moved eastward into Pisces (The Fishes).

When a superior planet is directly opposite to the Sun in the sky, astronomers call this opposition of the planet. At this time the Earth is between the Sun and the planet and the planet shines its brightest in the southern sky at midnight. It is closest to Earth, too. Inferior planets, Mercury and Venus, cannot reach opposition.

Conjunction occurs when a planet is on the part of its orbit directly behind the Sun as seen from Earth and thus is not visible in the night sky. The planet is then most distant from Earth.

Quadrature is when the planet appears 90 degrees away from the Sun in the sky.

SIGHTINGS AND MOTIONS OF JUPITER, 1973

Because the orbit of a superior planet is outside the orbit of the Earth, and because the Earth moves fastest, there is a period each year around the date of opposition when a superior planet appears to move backward—towards the west—among the stars, in what is termed retrograde motion. During 1973 Jupiter started to retrograde in June and continued moving westward until October when it halted and then went back to its normal eastward motion. (See drawing, Figure 1.)

Jupiter is easy to identify in the early evening sky. The bright star Vega is close to the Northern Cross (Cygnus) as shown in the star map of Figure 2. South of Vega are three close stars, the bright central one being Altair. An imaginary line from Vega through Altair leads towards the southwest horizon and to a bright star-like object—the brightest in that part of the sky. Shining more steadily than the stars, this is the planet Jupiter. Look at it through field glasses or a telescope and you will see that it is more than a star-like point. Also the several faint stars lined up nearby are the large satellites.

In October, 1973, about one hour after sunset when the sky has just become dark, Jupiter is almost due south. The planet appears a little more to the west each month until it is southwest in January as shown in Figure 2. Venus is in the same region of the sky and is brighter than Jupiter, but each month it is lower in the sky and closer to the horizon where the sun sets.

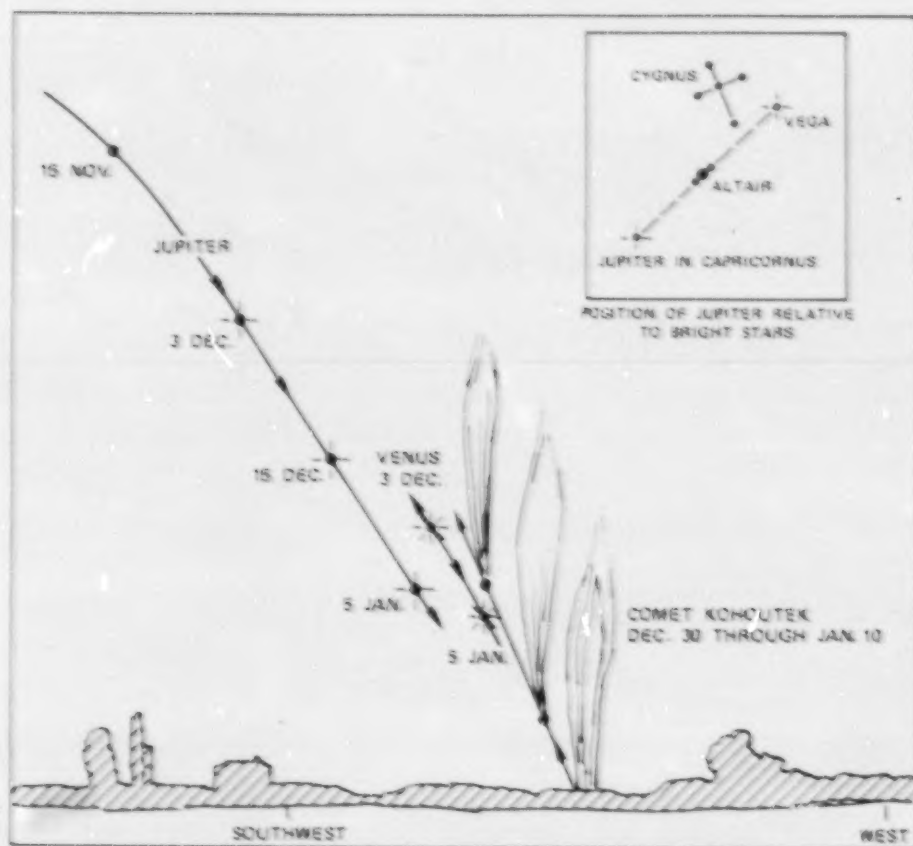


Figure 2. Positions of Jupiter, Venus, and Comet Kohoutek in Weeks Following Pioneer 10's Flyby of Jupiter (S.W. Sky About 1 Hour After Sunset)

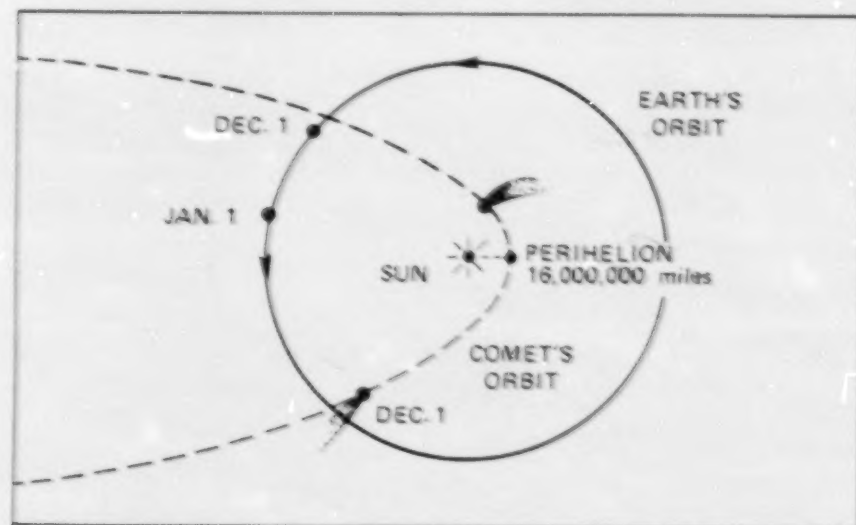


Figure 3. Relative Paths of Earth and Comet Kohoutek

Early in January, 1974, too, the tail of the bright comet Kohoutek is expected to appear above where the sun sets. And by mid-January the comet should move past Venus and Jupiter to form a spectacular trio in the early evening sky.

STUDY PROJECTS

ONE

Early in October look at the evening sky when it becomes dark about an hour after

sunset. The Sun sets in the west. Look left from the sunset point and thus to the southwest and make a sketch of the sky similar to that shown in Figure 2. Indicate the stars and name them from a star map. Find the planets Venus and Jupiter and place them on the sketch in correct position relative to the stars. In November, December and January do likewise. Note how the two planets move relative to the stars while the stars themselves all appear to be slipping, month by month, toward the sunset glow. Look out for the comet coming into view early in January and plot its path, too.

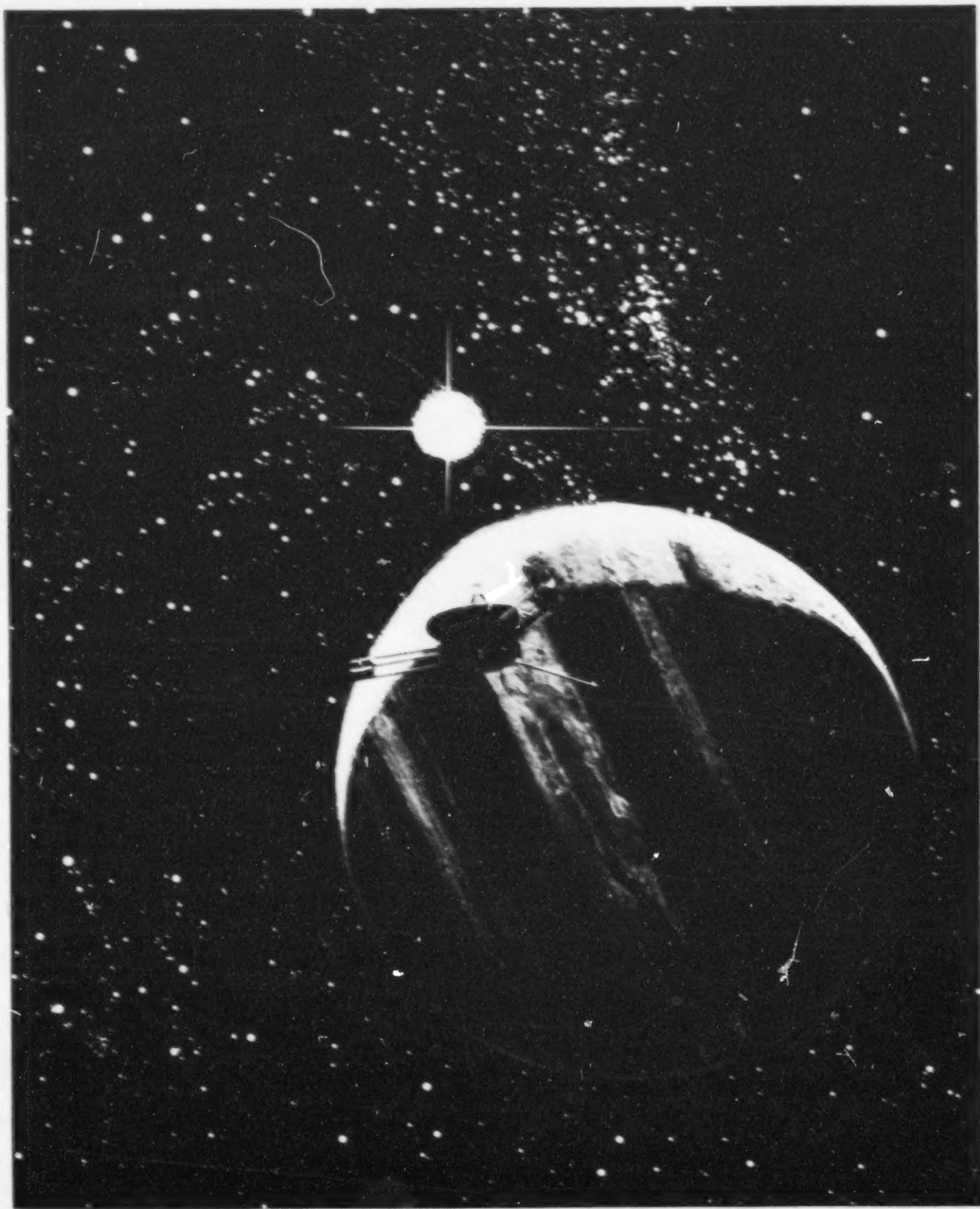
TWO

Refer to an astronomical textbook and draw a plan map of the Solar System showing the orbits of Earth, Venus (inside Earth's orbit) and Jupiter (outside Earth's orbit). Try to draw them to scale. Then try to work out where Earth and the two planets must be on their orbits to appear in the western sky as they do a few hours after sunset. Remember, as seen from above (North) the Earth rotates on its axis and all the planets revolve around the Sun in a counterclockwise direction. Jupiter was in opposition in 1973 at the end of July. You will have two possible positions for Venus, but since Venus is at its greatest brilliance in the middle of December, you can decide which is the more likely position for Venus (it is brighter when closer to Earth).

The orbit of comet Kohoutek is an elongated ellipse (see Figure 3). Try to place this ellipse on your map of the Solar System. The Figure shows the positions of the comet and Earth on December 1 and January 1 to help you. At its closest, the comet will be only 13 million miles from the Sun compared with the distances of Earth, 93 million; Venus, 60 million; and Jupiter, 485 million miles.

READING LIST

- Abell, *Exploration of the Universe*, pp. 23-26, 30 (Orbits).
- Driscoll, *Science News*, July 14, 1973, pp. 24-25 (Comet Kohoutek).
- NASA SP-268, *The Pioneer Mission to Jupiter*, pp. 1-3.



THE NOW FRONTIER

MAN LINKS EARTH AND PLANETS
PIONEER TO JUPITER



ISSUE NUMBER TWO

SE 017 037

JUPITER...AS A PLANET

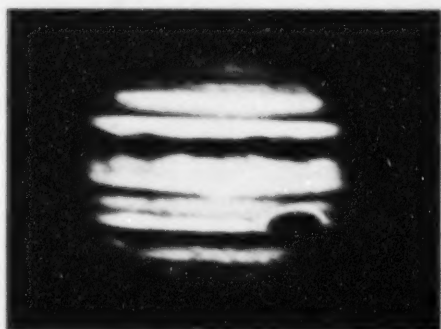
PHYSICAL CHARACTERISTICS

Jupiter is the largest planet of the Solar System—more massive than all the other planets combined. Its diameter from pole to pole is 77,000 miles compared with Earth's 8,000 miles. And the planet rotates faster than any other in the Solar System, turning completely on its axis once in every ten hours. This means that any point on its equator races along at 22,000 miles per hour compared with 1,000 miles per hour for a similar point on Earth's equator.

This high speed of rotation urges material on the equator to fly off into space. So the equatorial regions bulge outwards to make the equatorial diameter 1,900 miles greater than the polar diameter. The Earth is flattened at the poles in this same way but proportionately much less.

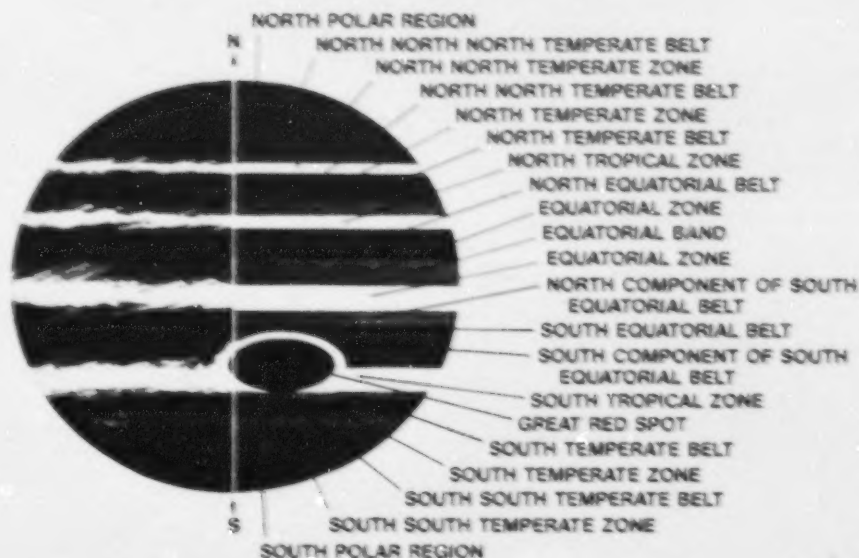
Although Jupiter's value is 1,000 times that of Earth, the planet has only 318 times the Earth's mass; it is said to be less dense. In fact it is only about one and one-third times as dense as water. Hence Jupiter cannot be a solid sphere like the Earth. Instead it must mainly consist of gas with possibly a small solid core. At least three-quarters of Jupiter probably consists of the lightest gases, hydrogen and helium, the same gases that are most common in the Sun and the stars. Jupiter is thus more like the Sun in composition than like the Earth.

Astronomers have detected other gases in Jupiter's vast atmosphere: methane and ammonia. But astronomers have not been able to see any solid surface, only masses of turbulent clouds.



Through a telescope from Earth (Figure 1), Jupiter appears as a striped, banded disc, with all the stripes parallel to the equator. Large dusky gray regions cover each pole. The dark, slate-gray stripes are called belts, and the lighter, salmon-colored bands between them are called zones. Several of the markings are permanent enough to be given names as shown in Figure 2.

JUPITER'S VISIBLE SURFACE



Over the years colors on Jupiter change; the zones vary from yellow and delicate gold to red and bronze, while the belts vary from gray to blue-gray. And the bands fade and darken as well as change color. They also widen and narrow and move up and down in latitude, that is, further from or closer to the equator. Some changes of color in the equatorial region appear to coincide with the 11.8 years period of Jupiter's revolution around the Sun.

It is thought that the cold tops of the Jovian clouds in the zones consist of ammonia crystals and vapor, while the gray bands may consist of condensed methane.

There is also a transparent atmosphere rising some 30 to 40 miles above the visible cloud tops.

Many smaller features are sprinkled among the zones and bands—streaks, wisps, arches, loops, patches, lumps, spots, some of which are probably knots of clouds. These small features often change form rapidly in days or even hours. Many are thousands of miles in size.

The cloud features of Jupiter move around the planet at different rates. For example, a great equatorial current sweeps around the planet at 255 miles per hour faster than regions on either side. And astronomers have detected that the clouds move at different speeds at different levels.

In the southern hemisphere of Jupiter there is a 30,000 mile long oval feature known as

the Great Red Spot. It has intrigued astronomers since first observed several centuries ago. The spot varies in intensity and several times it has completely disappeared. The spot presents the appearance of something floating in the atmosphere, like a raft or an island. One cloud current appears to sweep around it. Over several centuries the spot has drifted around the planet relative to the average movement of the clouds.

Some scientists believe that the Red Spot may be a column of gas, the center of an enormous whirlpool-like vortex rising from the surface to the top of the atmosphere. But it would have to be anchored in some way to the surface far below, perhaps by a deep hole or a high mountain.

There are also white spots which suddenly appear on Jupiter; they seem to be some kind of storm and can become quite bright for short periods of time. These, too, move relative to the other clouds.

RADIO WAVES FROM JUPITER

Jupiter emits three different types of radio waves. These radio waves are not like the signals that carry programs on our Earth radios but more like the static or noise that interferes with a program when lightning flashes or electric motors run nearby. The radio noise reaching Earth from Jupiter is greater than from any other source except the Sun. The three types are called thermal, decimetric, and decametric radiation.

Thermal radio waves are produced by molecules moving about in the atmosphere of

Jupiter. Decametric radio waves are produced by electrical discharges, like lightning flashes, in the upper atmosphere of Jupiter. Decimetric radio waves are produced by electrons moving about—oscillating—above the atmosphere.

The thermal radiation is at wavelengths less than a few centimeters. Decimetric are radio waves—about one tenth of a meter, to several centimeters (2.54 centimeters equals 1 inch). Decametric refers to wavelengths of tens of meters.

One interesting and as yet unexplained occurrence is that the decametric radio signals seem somehow to be linked to the passage of Jupiter's close moon, Io. In some unknown way Io appears to trigger the electrical discharges that cause these radio signals. These bursts of energy from Jupiter are equivalent to billions of simultaneous lightning flashes on Earth.

The decimetric radio waves from Jupiter lead scientists to conclude that the planet has radiation belts similar to those of Earth, and consequently that Jupiter must also possess an intense magnetic field that may be 20 times as strong as Earth's magnetic field.

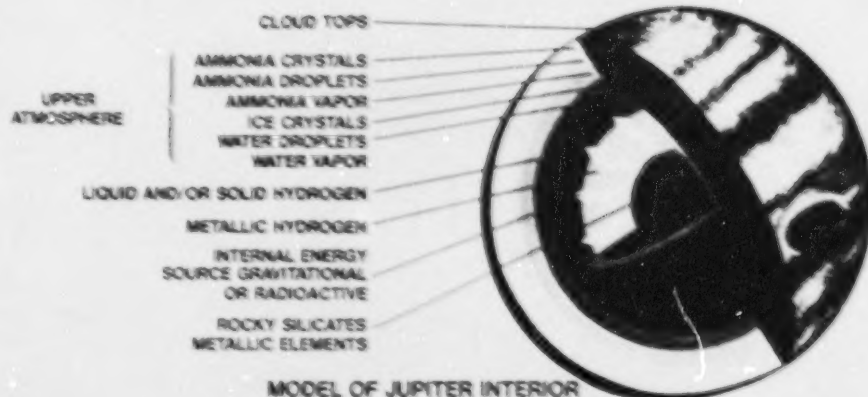
Radiation belts are produced by the magnetic field which traps electrons and protons (the nuclei of hydrogen atoms) that constantly flow through space from the Sun. These electrically charged particles oscillate backwards and forwards across the equator of the planet. This pendulum motion causes electrons to gyrate along the lines of force of the magnetic field. It results in radio waves being emitted similar to when electrons are caused to oscillate within a radio transmitter.

Thus, among the nine planets of the solar system, only Earth and Jupiter are known to have strong magnetic fields and radiation belts.

INTERNAL STRUCTURE OF JUPITER

Astronomers generally agree to a basic internal structure of Jupiter although they differ in detail (Figure 3). The average temperature on the top of the cloud layer is very low by Earthly standards, probably about -230 degrees Fahrenheit. Below the cloud tops the temperature rises steadily. The topmost regions consist of supercold ammonia crystals, ammonia droplets, and ammonia vapor. As temperature rises with increasing depth into the atmosphere, there may be ice crystals, water droplets, and water vapor present.

Estimates of the depth of the Jovian atmosphere below the cloud layer vary from 60 to 3,600 miles before any surface is reached, and this surface might be an ocean of liquid hydrogen rather than a solid surface.



At the bottom of the atmosphere the weight of all the gas above is enormous. The pressure exerted could reach a million times Earth's 14 pounds per square inch sea level pressure.

The great pressures can convert hydrogen into a special form in which the gas behaves like a metal; it readily conducts both heat and electricity as metals do. So beneath a sea of liquid hydrogen could be a shell of metallic hydrogen surrounding some final core consisting of rocky material and other metals somewhat the same as the composition of the inner planets including Earth. Jupiter's core has been estimated as ten times the mass of Earth.

This core might be very hot, as high as 20,000 degrees, because of pressure caused by the gravitational collapse of the huge planet due to the weight of the myriads of tons of matter above it. Such a hot core could account for Jupiter radiating into space about 3 times as much energy as it receives from the Sun.

LIFE ON JUPITER?

At first Jupiter might be considered an inhospitable planet on which life could never survive. This is not so. Since there are liquid water droplets in an atmosphere of hydrogen, methane, and ammonia, Jupiter provides the same kind of primordial 'soup' in which it is believed the first life evolved on Earth. And temperatures may be just right at some level in the atmosphere between the frigid cloud tops and the very hot core. In fact the heat coming from the core may supply the energy to make the atmospheric gases into complex carbon-based compounds needed to sustain life. On Earth, energy from the Sun makes these compounds through a process known as photosynthesis whereby simple life forms known as plankton assemble the chemicals in the oceans and higher life forms feed on the simple forms.

Floating in the Jupiter atmosphere there may be the equivalent of Earth's plankton, and Jupiter life might float and swim on the Jovian atmosphere and consume these carbon-based compounds as food.

But this is all speculation at present, and even the Pioneer probes aimed to fly past Jupiter soon will not be able to detect whether or not such life forms do exist on Jupiter.

STUDY PROJECTS

ONE

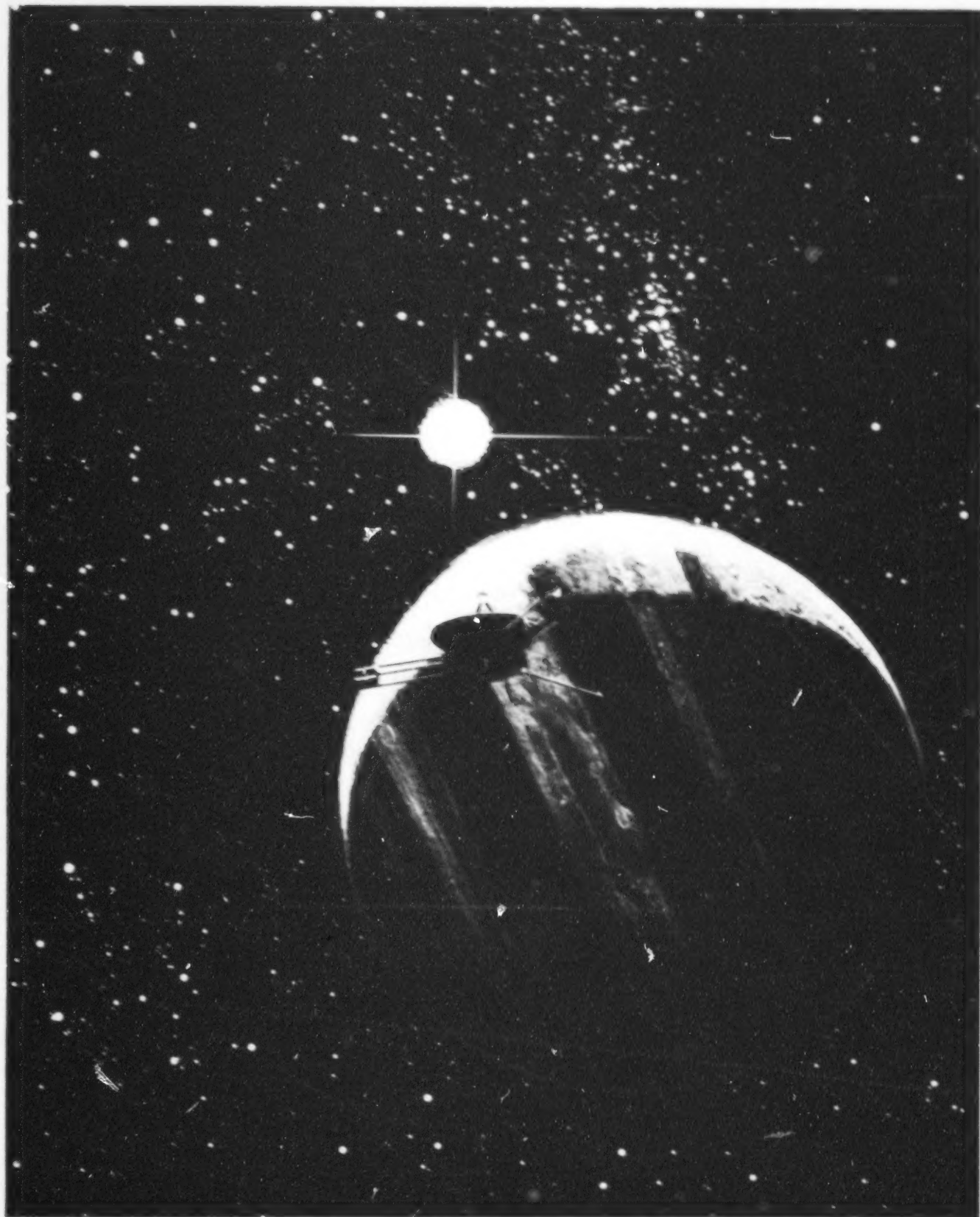
Make a large copy of the drawing of Jupiter shown in Figure 2, and lightly pencil in the various bands and zones. Obtain several astronomical textbooks from the library and read the sections on Jupiter. Examine any photographs and drawings in the textbooks. Then use your imagination to fill in details in the bands and zones even though these may not be shown clearly in any textbook illustrations. Color the resulting picture as you might imagine it might be seen from a spacecraft close to the planet.

When Pioneer 10 passes close to the planet early in December, 1973, it will radio back to Earth television pictures of Jupiter. These will appear on television screens and newspapers a few days later. Examine these pictures and see if they show the kind of detail you have drawn on the planet. Although the really close-in pictures will not show the whole of the planet they will provide details in parts. Check if your imaginary cloud patterns are similar to the close-up cloud patterns sent back by Pioneer.

TWO

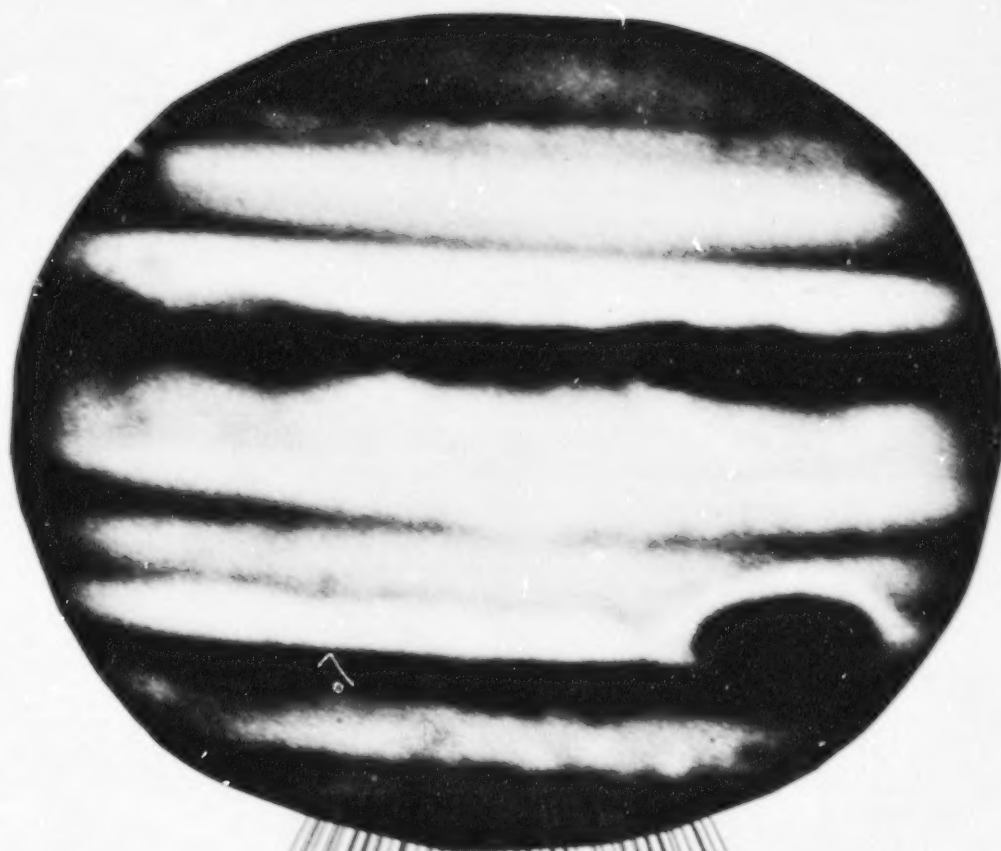
By reading the textbooks make a list of great unknowns concerning Jupiter: its structure, its atmosphere, its radiation belts, its Great Red Spot. Check with the later pamphlets in this series as to what the instruments of Pioneer will reveal, and identify those unknowns that can be solved by Pioneer.

Later check these with the actual results sent back by Pioneer as it passes close by Jupiter in early December.



THE NOW FRONTIER

MAN LINKS EARTH AND PLANETS
PIONEER TO JUPITER



ISSUE NUMBER THREE

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JUPITER AND PLANET EARTH

The question of beginnings has always intrigued people. How did something appear from nothing? All civilizations have tried to guess how the Universe, the Earth, and people originated. Early people thought everything was born from a universal mother. Today, steeped in the nuclear age, scientists suggest everything came from a big bang, a universal atomic bomb, about 13 billion years ago. Stars and their planets later condensed from the clouds of gas (hydrogen) that resulted from the creative explosion.

We are still far from having satisfactory answers as to how something (the universe) was created from nothing (the void) and even as to how the Solar System condensed from electrified atoms, darting molecules, and intertwining forces of some primeval mass of gas (nebula). How did the various planets evolve their unique characteristics? How did life blossom here on Earth?

It is not easy to find answers on Earth since this planet can be studied only in its present stage of evolution, a single frame in the long motion picture of Earth. And the single picture does not provide enough information for scientists to be sure about the past let alone Earth's probable future. However, other planets may pass through evolutionary history at different rates—some may be ahead, others lag behind Earth. So if these other planets are studied at close hand, by space probes rather than remotely by astronomical telescopes, they provide clues about Earth's history, development of natural resources, changes in atmosphere and their effects upon life processes, and expected evolution.

Knowledge about the other planets is important to our understanding Earth's past and future and is vital to the long-term survival of the human species if people are to adapt to inevitable natural and man-made changes to Earth's environment.

In many respects Jupiter models what takes place in the universe at large. Many processes on Jupiter are similar to those in a star (or the Sun) before its nuclear fire ignites. And the great turmoil of Jupiter's processes, coupled with high speed of rotation on its axis, provides a model for the study of jet streams and weather in the Earth's relatively quiet atmosphere.

Jupiter may also represent a stage paralleling an early period of Earth—the stage when life began to form here. In fact, Jupiter may be more favorable to life than any other planet, not excepting Earth.

And the circling satellites of Jupiter are a veritable Solar System in miniature. Their

formation may have paralleled the formation of the Solar System itself.

EVOLUTION OF PLANETS

Planets of the Solar System probably formed four to five billion years ago when hosts of small rocky particles and clouds of gases collected together by their own gravity. An idea can be gained of how long four billion years is by letting the thickness of this paper represent one year. Four billion years needs a stack of paper 200 miles high!

Gravity appears to be a universal property of matter as a result of which every particle, no matter how small, attracts every other. Thus, left to themselves in space, individual particles (and a gas also consists of particles) tend to collect together into large masses.

After the Sun itself condensed from a primeval nebula, planets of different sizes collected from different concentrations of matter present at various distances from the Sun. And electric and magnetic forces in the gas clouds probably thrust these condensing planets into orbits around the central Sun. If one planet started early it scooped up more matter than those starting later with less free material to collect. The oldest craters on Mars and craters on the Moon are thought to be evidence of the final stages of planetary accretion as this process is called (Figure One).

Much of the primeval gas was hydrogen—the most common material in the universe—which consists of a proton and a circling electron. The Sun, for example, is nearly all hydrogen, as are the stars. And astronomers have discovered vast clouds of hydrogen in the spaces between stars.

While it is most probable that the Earth as it formed was never able to pull to itself much hydrogen, it might have possessed some in its atmosphere for a short while. The closeness of the Earth to the Sun makes the Earth too warm to hold free hydrogen for long. Hydrogen escapes like steam bubbling from a hot saucepan. Most hydrogen remaining on Earth is locked with oxygen to form molecules of water—the Earth's oceans.

Similarly, the Moon, Mercury, Venus, and Mars cannot hold hydrogen. They would need to be much larger—have much stronger gravity—to prevent hydrogen 'boil-off' from heat due to their closeness to the Sun. But cooler Jupiter, 350 million miles beyond Mars, also has a strong gravity which holds hydrogen in tremendous quantities. So do the other large, distant planets: Saturn, Uranus, and Neptune.

Jupiter, if stripped of its hydrogen, might be a solid planet not much larger than the inner planets. So all the outer planets may really

be inner-type planets surrounded by very deep atmospheres.

THE ATMOSPHERE

Knowledge about these complex atmospheres may help us to understand Earth's more simple atmosphere. Already the study of dust storms in Mars' very thin atmosphere is helping Earth's meteorologists.

At some level in the deep atmosphere of Jupiter—an atmosphere of hydrogen seasoned with helium, methane, ammonia, and water—the temperature should equal that on Earth. At this level ammonia crystals detected in Jupiter's cloud tops become liquid ammonia droplets. Water condenses, too. The droplets rain 5 m the clouds, sometimes frozen into snows of water and ammonia. But the drops and the snowflakes could never fall to the surface as they do on Earth. Instead, at warm lower regions of the deep atmosphere, they again must evaporate and rise back into the clouds.

The circulation must cause endless violent turbulence in the Jovian atmosphere, more violent than any thunderstorms of Earth. And accompanying electrical discharges make Earth's lightning flashes mere sparks by comparison.

Thus the vertical movements in the atmosphere of Jupiter provide models of the most violent storms imaginable. At the same time the jet circulations in the cloud bands and zones, described in the second pamphlet of this series, compare to Earth's major atmospheric patterns, trade winds and jet streams.

Studies of the cloud patterns of Jupiter and their motions can help us understand how Earth's atmosphere circulates and how hurri-

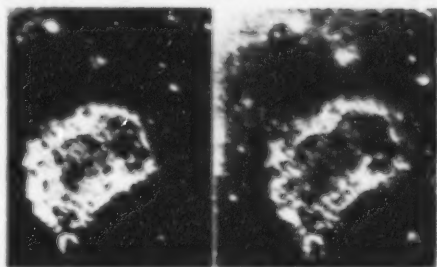
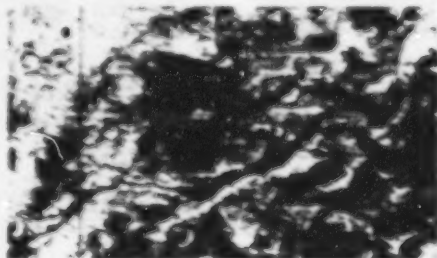


Figure 1. Craters on Mars (top photo) and Moon (bottom photo).

canes and other disastrous weather systems originate. Perhaps we shall also find ways to control Earth's bad weather and prevent floods and wind damage.

RADIATION BELTS

Among the planets only Earth and Jupiter are known to have radiation belts (Figure Two), the result of strong magnetic fields whereby both planets behave like big magnets and trap charged particles from space. These particles, electrons and protons, race along lines of force produced by the magnetic field. (On Earth it is this same field that causes the needle of a magnetic compass to point toward the north.)

Jupiter's stronger magnetic field traps more particles. So its radiation belts extend 255,000 miles above the cloud tops (further than the distance from Earth to Moon) and contain at least 100 trillion times the energy of Earth's belts. Major questions are: why Jupiter's magnetic field is so strong compared with Earth's, and are the two fields caused the same way.

Radiation belts are important because their speeding particles can affect instruments carried by spacecraft and even upset control of a spacecraft. Many missions to explore the outer solar system require spacecraft to approach close to Jupiter to use its gravity as a slingshot. This considerably shortens the long times needed to reach, say, Neptune or Uranus. But if Jupiter's radiation belts damage spacecraft we cannot use this slingshot technique.

Radio waves tell us about the number of electrons in the belts. But it is the protons in the belts that are damaging. These can only be measured by carrying instruments into the belts. Pioneer 10 will do this early in December. Then we should know how much we can use Jupiter as a slingshot for subsequent missions to the outer planets as well as learn much more about radiation belts in general.

SATELLITES

Two satellites of Jupiter are as large as Mercury. They could possess atmospheres. Some satellites have odd characteristics. The close, large satellite, Io, normally a very bright world, is brighter still when it first emerges from Jupiter's shadow. Could this be frost or snow evaporating? If so, it would mean that the satellite has an atmosphere. Astronomers question whether these satellites have features of earth-like inner planets or are more like giant snowballs.

The four outermost small satellites, Androsta, Pan, Poseidon, and Hades, move around Jupiter in a counter direction to most of the Jovian satellites. They could be captured asteroids.

PIONEER PASSAGE THROUGH JUPITER'S MAGNETIC FIELD AND RADIATION BELTS

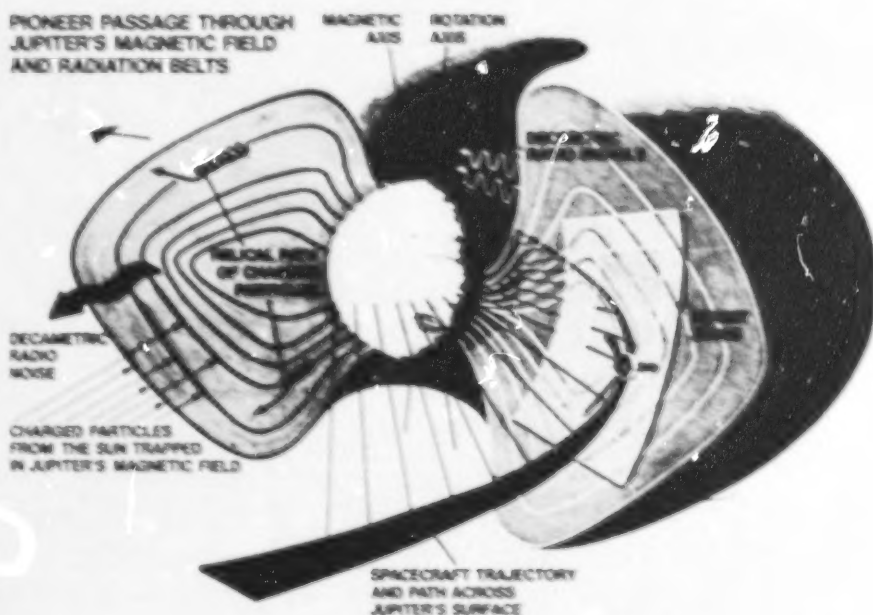


Figure 2. Jupiter's radiation belts (NASA picture).

Pioneer spacecraft will get close looks at the larger satellites and help to resolve current mysteries about them.

EVOLUTION OF LIFE

Life might be described as an unexplained force that somehow organizes inanimate matter into a living system that perceives, reacts to, and evolves to cope with, changes to the physical environment that threaten to destroy its organization.

In 1953 a mixture of hydrogen, methane, ammonia, and water vapor—the kind of atmosphere the Earth probably had soon after it was formed and the kind Jupiter has today—was treated in a laboratory. Scientists passed electrical discharges through the gas mixture to obtain the same effect as bolts of lightning. The result was surprising and important. The electrical energy changed some of the simple gases into more complex mixtures of carbon, hydrogen, nitrogen and oxygen, new molecules that we believe to be the essential building blocks for living systems.

We conclude that natural processes such as lightning and ultraviolet light from the Sun (the light that sunburns) can produce complex chemicals to form building blocks for living things. In fact, some of the complex chemicals are found in the space between the stars and on meteorites (the familiar 'falling stars'): small rocks that plunge into the Earth from outer space.

At some point in the past, probably about 3½ billion years ago, something organized the complex carbon-based molecules into living systems which were then able to make copies of themselves—to reproduce. From then on, by slight changes to subsequent copies, biological evolution produced all the living creatures of Earth. And at one stage a special consciousness appeared that gave rise to Man himself (Figure Three).

A big question is whether life has evolved in this way in the atmosphere of Jupiter. It is known that temperatures could be right. It is known that the gas mixture is right. It is known that electrical discharges take place. Studies of the Great Red Spot suggest it may be rich in amino acids, an important stage in building the living cell which is the simplest form of life.

While the Pioneer spacecraft is not designed to answer directly the question of life on Jupiter or its satellites (we would need a spacecraft to enter the atmosphere of Jupiter), these spacecraft will add considerably to knowledge about the physical processes taking place in Jupiter's atmosphere. They should also provide close looks at some of the big satellites. Thus these Pioneers will contribute to a better understanding of whether or not life could exist in the Jovian system.

Jupiter may, indeed, hold keys not only to the origin of life but also to secrets of the stars, for Jupiter is almost big enough to be a star in the making.

STUDY PROJECTS

ONE

Assuming that electrical discharges created living systems in Jupiter's atmosphere and that amino acids continually drift down from the clouds as food, a kind of "manna from heaven," use your imagination to draw the type of life that might have evolved. Remember that the atmosphere is very stormy with swift and furious winds and powerful currents so the life form would have to be able to move about quickly—wings, jets from gas bags? And would other life forms evolve as on Earth to prey on lesser creatures? Draw or paint a picture depicting life as it might be in the atmosphere of Jupiter.

TWO

Read astronomical textbooks and make three lists: a) those things on or about Jupiter that are similar to their counterparts on Earth, b) those that are different, and c) unanswered questions about Jupiter. Make notes on how further information about these similarities and differences and answers to the questions can aid in understanding Earth. When Pioneer 10 flies by Jupiter this December update your list and check off those unknowns which are then answered.

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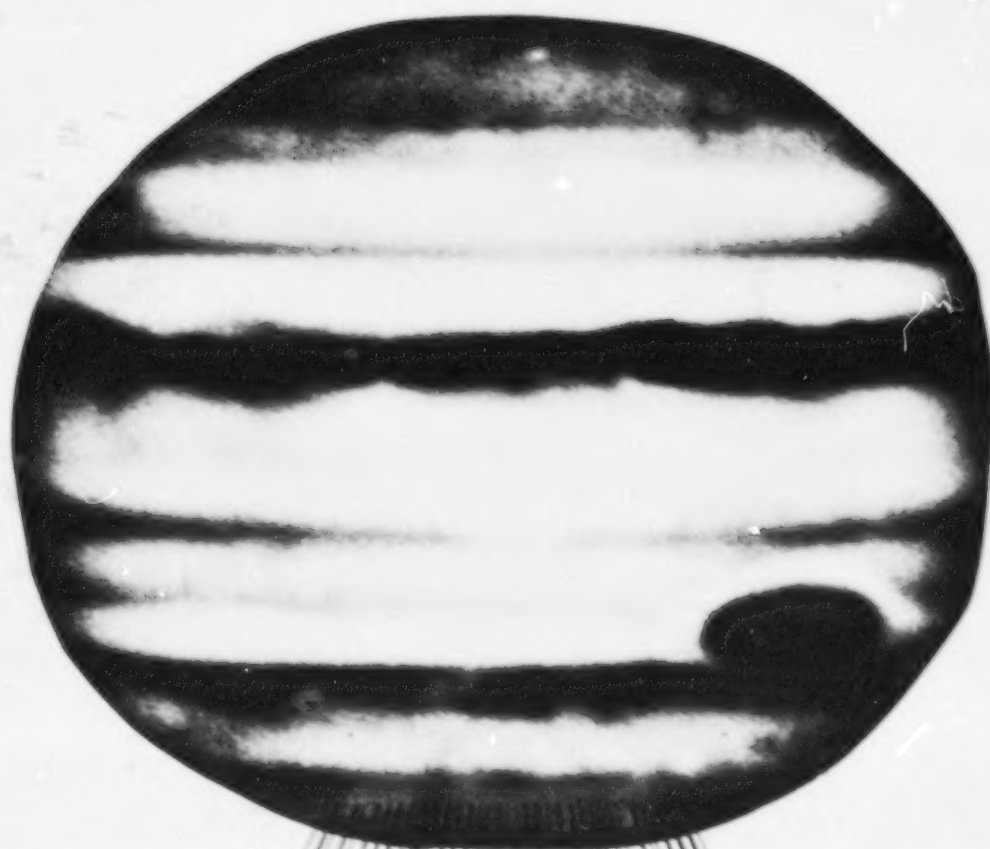
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TIME	GEOLOGIC ERA	LIVING SYSTEMS EVOLVE	EARTH CHANGES
PRESENT		MAN (CONSCIOUSNESS)	ICE AGE (MOST RECENT)
	CENOZOIC		
	MESOZOIC	FIRST MAMMALS	
	PALEOZOIC	CREATURES WITH SPINES	CLOSE TO PRESENT DAY ATMOSPHERE
1000		FIRST MULTI-CELLED CREATURES	
2000			OXYGEN INCREASES
3000	PRE CAMBRIAN		ATMOSPHERE ENRICHED WITH OXYGEN BY ALGAE
		FIRST MICROFOSSILS (ALGAE, BACTERIA)	ATMOSPHERE WATER, METHANE, AMMONIA, AND POSSIBLY HYDROGEN
4000		EVOLUTION OF CARBON COMPOUNDS (THE BUILDING BLOCKS OF LIVING SYSTEMS)	A CRUST AND WATER OCEANS
	EARTH FORMATION	TOO HOT AND CHAOTIC FOR LIVING SYSTEMS	AN EARTH SPHERE FORMS
5000			PARTICLES GASES A FORMLESS VOID

Figure 3. The evolution of living systems.

THE NOW FRONTIER

MAN LINKS EARTH AND PLANETS
PIONEER TO JUPITER



ISSUE NUMBER FOUR

5E 017 037

MISSION TO JUPITER

Pioneer 10 will reach Jupiter on December 3 after a 22-month, 620 million mile trip. It has already set many records. Pioneer traveled faster and further than any other man-made object. Its tremendous launch speed of 32,114 miles per hour from an Atlas-Centaur rocket on March 2, 1972, carried it beyond the Moon in 11 hours. But even this speed will be outdone at the closest approach to Jupiter when that planet's gravity causes Pioneer to hurtle past at 82,000 miles per hour.

Pioneer 10 is the first spacecraft to fly beyond Mars' orbit, the first to cross the Asteroid Belt. It should also be the first man-made device to leave the Solar System entirely and fly off among the stars of the Milky Way, the Galaxy.

And the spacecraft flies with unbelievable accuracy: after nearly two years of flight through space it is scheduled to arrive at Jupiter within less than one minute of the planned time.

A second Jupiter-bound spacecraft, Pioneer 11, was sent after the first on April 5, 1973.

THE SPACECRAFT AND ITS PATH

Pioneer 10 and its companion are the first spacecraft designed to travel into the outer Solar System and to operate there for as long as 7 years and as far from the Sun as 1.5 billion miles, possibly more. For such a mission a spacecraft needs extreme reliability; nothing must fail. And the spacecraft must be lightweight so that its booster rocket can accelerate it to the high speed needed. It must have a communication system that can operate over vast distances, and since it cannot rely on the Sun for power when so far away, it must carry its own nuclear power units.

The two Pioneers are stabilized by rotation, like spinning tops. Both are controlled largely from Earth since on-board computers would be too heavy.

The Pioneers are almost identical. Each is 9½ feet long from the cone-shaped antenna horn sticking out from the dish of the communication antenna, to the other extreme of its structure (Figure 1). The spacecraft's spin axis and the center line of the dish antenna are parallel. Equipment is stored in a flat, hexagonal-shaped box beneath the antenna. Scientific equipment for experiments is housed in a smaller box attached to one side of the larger. Some science equipment is mounted outside of the two boxes.

Two structures of rods extend from the spacecraft to carry nuclear power generators at their ends. These generators convert energy

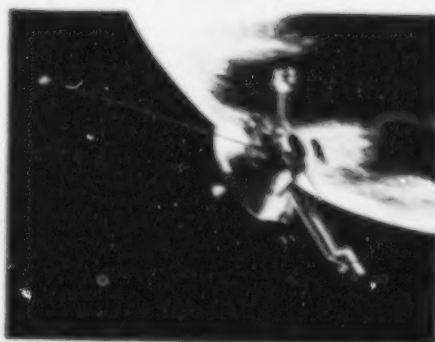


Figure 1. Pioneer Jupiter Spacecraft

from the atomic breakdown of Plutonium-238 into electricity. They are expected to provide power for at least five years after launch.

A third, single rod extension carries more scientific equipment. All the booms were extended in flight after launching.

Small rocket jets change the velocity of the spacecraft, change its attitude, or change its speed of rotation. They are controlled by commands from Earth or automatically by commands stored in the spacecraft's electronic memory. An automatic system also uses these thrusters to keep the spin axis, and therefore the communications antenna, pointed directly towards Earth.

The Pioneers follow a curved path to Jupiter—some 620 million miles long covering about 160 degrees around the Sun between the orbits of Earth and Jupiter (Figure 2). About 120 days after launch each Pioneer enters the Asteroid Belt, a zone of small planetary bodies between the orbits of Mars and Jupiter. The largest of these bodies is Ceres, 480 miles in diameter. Most are very much smaller. A planet was probably prevented from forming here because of the influence of Jupiter, and astronomers thought that the region might be strewn with high velocity debris down to the size of specks of dust.

The number of small particles was unknown and could have presented a major hazard to spacecraft traveling to the outer planets.

Almost 300 days after launch, Pioneer 10 passed on the far side of the Sun from Earth. Radio communication was interrupted for a few days.

With Pioneer 10 well on its way through the Asteroid Belt without incident, the second spacecraft, Pioneer 11, was launched on a very similar path to Jupiter. Leaving April 5, 1973, it is scheduled to arrive at Jupiter a year after Pioneer 10, namely in December, 1974. Its path is ordered so that, depending upon the findings of Pioneer 10, the second Pioneer can fly closer to or further from Jupiter, fly to Saturn in 1980, or follow Pioneer 10 out of the Solar System.

WHAT THE SPACECRAFT DO

Both spacecraft are designed to investigate Jupiter in three ways:

- 1) measurements of particles, fields, and radiation
- 2) television imaging to provide pictures of the planet and several of its satellites
- 3) accurate observation of the path of the spacecraft to measure the forces (such as the gravity of Jupiter) acting upon it.

The spacecraft also provides information on interplanetary space from the Earth's orbit to the orbit of Saturn and beyond.

A number of experiments have been designed with the objectives listed.

INVESTIGATION OF INTERPLANETARY SPACE ON THE WAY TO AND BEYOND JUPITER

- Map the magnetic field in interplanetary space between Earth's orbit and Jupiter's orbit, and beyond.

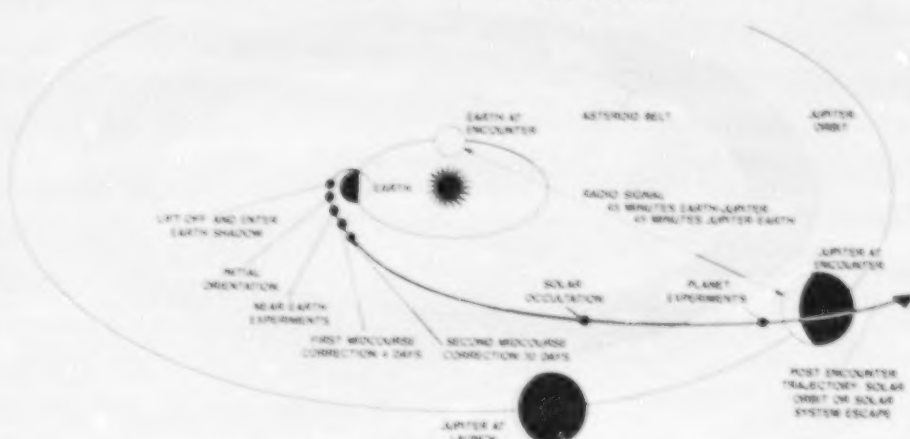


Figure 2. Mission Events

- Determine the changes and the arrival direction of cosmic rays—fast moving parts of atoms—rushing out from the Sun and also into the Solar System from the Galaxy.
- Determine how the solar wind—a flow of charged particles from the Sun—varies with distance from the Sun.
- Ascertain any relationships between the solar wind, the interplanetary magnetic field, and cosmic rays.
- Search for the end of the solar atmosphere (the heliosphere).
- Determine the properties and density of interplanetary dust.

INVESTIGATION OF THE JOVIAN SYSTEM

- Map the magnetic field of Jupiter.
- Determine the numbers and types of charged particles in the radiation belts of Jupiter, and the extent of these belts.
- Check if Jupiter has auroras like the Earth does (glows in the upper atmosphere over the polar regions).
- Try to find out what causes the decimetric and decametric radio waves from Jupiter.
- Detect and measure a shock wave between the magnetic field of Jupiter and the wind of charged particles from the Sun, like the bow wave of a ship.
- Measure the temperature of the outer atmosphere of Jupiter above the cloud tops.
- Measure the proportions of hydrogen and helium in Jupiter's atmosphere.
- Measure the structure of the planet's visible atmosphere and also of the higher regions where molecules of gases become electrically charged and produce an ionosphere.
- Measure the brightness, color, and polarization (the direction of vibration) of reflected light from Jupiter.
- Photograph Jupiter from a distance, and later close to, with better resolution than that obtainable from Earth; obtain pictures of the terminator (the region of sunrise and sunset) and of a crescent Jupiter with the Sun shining from behind the planet.
- Photograph the satellites from a distance, and some of them close-up; measure their

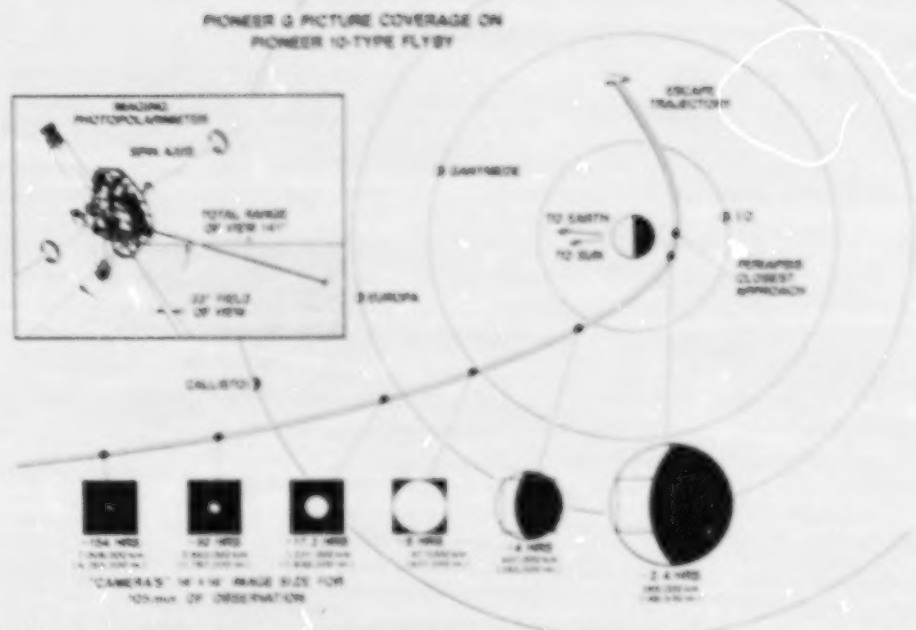


Figure 3. Picture Coverage at Encounter

sizes and determine which, if any, possess an atmosphere.

- Calculate with greater accuracy the orbits and masses of the satellites and the gravitational field of Jupiter itself.

To achieve these objectives each spacecraft uses a battery of scientific instruments. These include a magnetometer to measure magnetic fields, a plasma analyzer to measure the ions and electrons flowing through space from the Sun (solar wind), a composite device to detect and measure electrons and protons in the radiation belts and nuclei of chemical elements from hydrogen to oxygen, and a cosmic ray telescope to detect and measure cosmic rays.

A geiger tube telescope and a radiation detector also detect and measure particles in the radiation belts.

An asteroid-meteoroid detector measures paths of space particles in the vicinity of the spacecraft to find the distribution of dust and other particles in the space between the planets of the Solar System, and in the vicinity of Jupiter. A meteoroid detector also keeps tags on these particles as they puncture its pressurized cells.

An ultraviolet photometer (light measurer) and an infrared radiometer (heat measurer) look at interplanetary space and the Jovian system in ultraviolet and infrared—the radiation on either side of the visible spectrum of

light that extends from violet to red (the colors of the rainbow). The ultraviolet instrument determines how much helium exists in the atmosphere of Jupiter, and how much hydrogen and helium is flowing into the Solar System from the Galaxy. The infrared instrument measures heat radiated from Jupiter and from features such as the Great Red Spot. It also checks the proportions of hydrogen and helium in the atmosphere.

An imaging photopolarimeter moves a narrow beam in sweeps across the surface of Jupiter and builds up a picture like a television set builds its picture by a series of lines across the tube face. The instrument measures the intensity and the polarization (how the light waves are vibrating) of light from Jupiter and its satellites. It is also used to scan space on the way to Jupiter. This instrument, through a computer back on Earth, provides television-type images—pictures of Jupiter that are expected to be better than those obtained by telescopes from Earth and at viewing angles impossible from Earth. Textures and shapes of clouds should be seen.

Pictures also will be constructed of Jupiter's large Galilean satellites. Since radio signals are continuously coming from the spacecraft to Earth, these can be used to probe into the atmosphere of Jupiter and the satellite, too, by measuring fading of these signals when the spacecraft passes behind Jupiter and the satellite. This experiment provides information about the composition and density of the atmosphere, and the numbers of electrons moving freely in it.

BEFORE ENCOUNTER

From leaving Earth's orbit many of these instruments have been gathering important information about space. Already they have produced significant results.

First, they traced the solar wind and its particles far from the Sun, further than ever before. They found that the wind slows down but becomes more turbulent. They also found that high energy particles emitted by the Sun include the elements sodium and aluminum. Another surprise was the discovery that the hydrogen flowing into the Solar System does not come from the direction to which the Sun and its retinue of planets is moving, but seems to flow along the plane of the Earth's orbit. There is no explanation.

Helium from the Galaxy was also detected flowing into the Solar System. But Galactic cosmic rays appear to be screened somehow by the turbulent solar wind. It stops low energy particles from coming in from the Galaxy inside the orbit of Jupiter at least.

The spacecraft's instruments looked at interplanetary particles, particularly those in the asteroid belt which might be a hazard to spacecraft. Some surprises resulted. The smallest particles declined in numbers as the Pioneer moved out from the Sun. Somewhat larger particles were evenly distributed with no increase in the asteroid belt. However still larger particles did become three times as numerous in the belt. Other instruments confirmed these results. Thus Pioneer 10 has proved that the asteroid belt does not have myriads of dangerous small particles. Instead it consists of much less numerous larger particles. It does not present the hazard to spaceflight once thought. There may be even fewer small particles in the belt than near Earth.

THE ENCOUNTER AND AFTER

In late November 1973 Pioneer 10 glides in towards the brightly colored and enormous Jupiter—passing the four small outer satellites at 25 days before closest approach, the three middle satellites at 11 days, and, in the grip of the immense gravity, the four planet-sized Galilean satellites and the tiny inner moon in a rush on the day of closest approach, December 3.

At the closest approach to 81,000 miles, Jupiter fills the black sky, an enormous yellow-orange and blue-gray-belted sphere. And six hours earlier, Pioneer begins to test the intense radiation belts while controllers on Earth anxiously await confirmation that the belts are not damaging the equipment of the spacecraft.

Low resolution pictures are taken of the five inner satellites and of Jupiter itself, while the battery of instruments probe into surrounding space, the satellites and the planet.

Spacecraft operation during the encounter are complicated by 92 minutes of round trip time for radio signals to pass back and forth and a need to send 10,000 commands to the spacecraft in the two weeks centered on closest approach.

After Jupiter, Pioneer 10 heads out of the Solar System, crossing Saturn's orbit in 1976, Uranus' orbit in 1979, Neptune's orbit in 1983, and in 1987, 15 years after launch, the orbit of Pluto, the known limit of the Solar System. Pioneer's destination among the stars of the Galaxy is then somewhere in the Zodiacal constellation of Taurus (The Bull). The spacecraft heads out from the Solar System at 25,000 miles per hour carrying a plaque that tells any intelligent species who may find it millions or billions of years from now, who sent it and from where it came.

A project of NASA's Office of Space Science, the Pioneer project is managed by NASA's Ames Research Center, near San Francisco, California. The two spacecraft are built by TRW Systems, Redondo Beach, California. The scientific instruments are supplied by NASA Centers, universities, and private industry. Tracking is by NASA's Deep Space Network, operated by the Jet Propulsion Laboratory, Pasadena, California.

STUDY PROJECTS

ONE

On the map of the Solar System, made as a project for leaflet #1 of this series, draw the path of Pioneer 10. Work backwards from the encounter on December 3 using Figure 2 as a guide to find the position of the Earth at launch. Put the path of Pioneer 11 on the map, too, using the correct positions of Jupiter and Earth for the launch and encounter dates. Remember Earth goes twelve times around the Sun when Jupiter goes around once.

TWO

If Pioneer 10 leaves the Solar System at 25,000 miles per hour 15 years hence and heads towards the stars at this constant speed, calculate how long it takes to reach the distance of the near star, Proxima Centauri, which is 4½ light years away. (A light year is the distance light, speeding at 186,000 miles a second, travels in one year). Calculate how fast a spacecraft has to travel to reach this near star in 10 years.

READING LIST

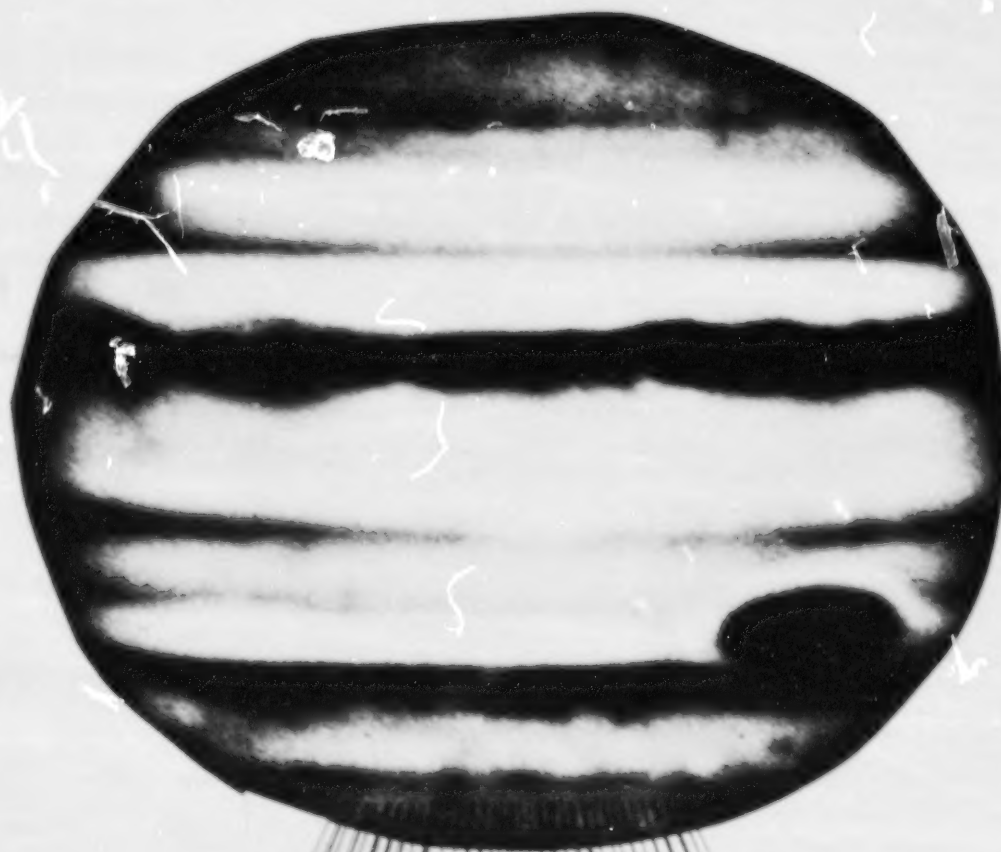
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THE NOW FRONTIER

MAN LINKS EARTH AND PLANETS
PIONEER TO JUPITER



ISSUE NUMBER FIVE

LEO 6/10 25

ENCOUNTER WITH JUPITER

PIONEER TO JUPITER, ENCOUNTER WITH JUPITER

At precisely 6:26 p.m. PST on December 3, 1973, Pioneer 10 will hurtle past Jupiter only 81,000 miles above the cloud tops (Figure One). During the two weeks around that date a team of spacecraft controllers, analysts, and scientists at NASA's Ames Research Center, and personnel of NASA's Deep Space Network, will run a three-shift, 24-hours-a-day control operation. Constantly alert to danger to the spacecraft from possible but unpredictable problems due to unknowns in the environment of Jupiter, these men will send up to 15,000 commands to the distant spacecraft during this period.

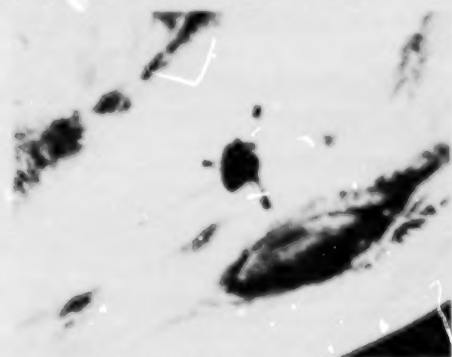


Figure 1. Pioneer flying over the Great Red Spot.

They have been rehearsing their roles for months now, getting prepared to tackle every conceivable problem that might arise to endanger this first mission to Jupiter, giant of the Solar System.

Their job is complicated by the 92 minutes needed for signals to reach Jupiter. To save weight and keep the cost of the spacecraft low, the Pioneers are controlled by people sending commands from Earth rather than making the spacecraft completely automatic. But controllers have to wait an hour-and-a-half from sending a command to knowing the spacecraft has done what they want it to do. That's the time that radio waves, traveling at 186,000 miles per second, take to travel to the spacecraft and back.

Well in advance of Jupiter encounter, the men at Pioneer control turn on most of the spacecraft's subsystems and scientific instruments. They leave them operating throughout the encounter. If all goes well only a few routine spacecraft operations will then need to be commanded, such as checking that the pointing direction is correct so that signals are directed accurately toward Earth, or changing, as needed, the precise order in which information is returned to Earth. Only 5 of the 11 scientific instruments require commands. Most commands are to direct the sequence of pictures of Jupiter and its satellites.

In the months before encounter controllers test all the backup systems of the spacecraft so that spares carried aboard can be switched on to take over if some equipment fails as the spacecraft encounters the Jovian environment. For example, the radiation belts might seriously damage equipment and scientific instruments, and charged particles might stick to the spacecraft, especially when it is in Jupiter's shadow, and arcing could produce false commands to it.

Also, the mighty gravity of Jupiter could pull the spacecraft askew on its spin axis. And the spinning of the spacecraft could itself produce problems, turning the spacecraft into an electrical generator as it spins in Jupiter's magnetic field.

Finally, Jupiter could possess dust belts in a ring around the equator. While this dust would be invisible from Earth, impact with it could damage the spacecraft as it moves through the plane of Jupiter's equator just after closest approach to the planet.

So the men of Pioneer control have to be on their toes every second of the encounter period, ready to issue correcting commands to right any problems that might arise.

News from the spacecraft arrives back at Earth on three large antennas—210-foot dishes as large as football fields. One is in the Mojave Desert at Goldstone, California. Another is at Madrid, Spain, while the third is near Canberra, Australia. As the Earth turns on its axis, and the spacecraft with Jupiter sets at one of these Earth stations, the spacecraft rises at the next station. So signals can be received 24 hours each day.

And these giant antennas—the last two were completed and put into operation while Pioneer was on its way to Jupiter—can track the

spacecraft to the enormous distance of more than 1.5 billion miles. Then the signals will take 4 hours to reach Earth.

THE ENCOUNTER SEQUENCE

Because Jupiter's gravity bends the spacecraft's course, the actual fly-by is a wide loop around the planet. Pioneer 10 approaches from Jupiter's sunlit side, then swings almost completely around its dark side. Planet rotation aside, Pioneer 10 flies two-thirds of the way around Jupiter at various distances. During the 48 hours of closest approach of Pioneer, Jupiter completes five rotations on its axis.

Pioneer 10 approaches in a counterclockwise direction—the same direction as Jupiter rotates—as seen from above the planet's north pole. Its path on the planet's surface passes over part of Jupiter's southern hemisphere, crosses the equator at an angle of 14 degrees, and leaves the planet over the northern hemisphere.

There are five stages in the two-month Pioneer encounter period from November 4, 1973 through January 3, 1974. (See Table One.) Stage One is the three weeks, November 4 through 24, during which the spacecraft passes from interplanetary space into the outer regions of the Jovian system, moving from about 15 million to 6 million miles from the planet.

Stage Two covers entry into the inner system. Sometime between November 25 and 29, Pioneer is expected to pass through the bow shock wave in the solar wind created by Jupiter's magnetic field and thus enter this magnetic field, the magnetosphere, of Jupiter.

Stage Three is that period when Pioneer continues flying through the outer magne-

TABLE 1. DISTANCES DURING ENCOUNTER

DATE	TIME	DISTANCE FROM JUPITER, MILES	STAGE OF ENCOUNTER
NOV.	8 2:26 A.M.	14,680,000	1
	11 10:26 A.M.	12,821,000	
	22 6:26 A.M.	7,084,000	
25	6:26 P.M.	5,180,000	2
	27 6:26 P.M.	4,077,000	
	28 6:26 P.M.	3,508,000	
	29 6:26 P.M.	2,123,000	
	30 6:26 P.M.	2,313,000	
DEC.	1 6:26 P.M.	1,666,000	3
	2 6:26 P.M.	943,800	
	3 6:26 P.M.	81,000	4
	4 6:26 P.M.	948,256	
	5 6:26 P.M.	1,660,000	5
	6 6:26 P.M.	2,313,000	
	7 6:26 P.M.	2,922,000	
	8 6:26 P.M.	3,508,000	
	9 6:26 P.M.	4,076,000	
	10 6:26 P.M.	4,633,000	
	11 6:26 P.M.	5,180,000	

sphere from about 3 to 2 million miles from the planet during November 30 through December 2.

Stage Four is the period of closest approach. It covers the last day and a half (38 hours) before closest approach of 81,000 miles on December 3. Here is where the spacecraft makes its most important measurements and flies by the big inner satellites. It takes hundreds of pictures and flies through the radiation belts.

Stage Five takes place as Pioneer flies away from Jupiter and repeats many of the earlier sequences in reverse order.

On November 8, during Stage One of the encounter, Pioneer 10 crosses the orbit of

Hades, outermost satellite of Jupiter (Table Two). In the next few days it successively crosses the orbits of Pan and Andraستا. By November 11 Pioneer crosses the orbit of Demeter at 7 million miles from Jupiter, then Hera and Hestia. But the Jovian system is so big that despite the high speed of Pioneer it is not until December 3, the day of closest approach, that Pioneer crosses the orbits of the inner satellites. It comes within 865,200 miles of Callisto, which is as large as the planet Mercury. Next is close approach to Ganymede (larger than Mercury) of 277,300 miles, then to within 199,470 miles of Europa (size of Earth's Moon), and 221,840 miles of Io (larger than Moon). Pioneer approaches to 11,470 miles of the

orbit of the innermost satellite Amalthea, but does not cross it.

First evidence at the spacecraft of Jupiter's presence may come on November 25 as Stage Two of the encounter begins. This is the earliest date for passage through the bow shock wave created as the solar wind hits the planet's magnetic field (see Table Three). The earliest date for entering Jupiter's magnetic field is November 29. Studies of this field can tell us about Jupiter's interior and more about the intense radio signals from the planet.

The first ultraviolet inspection of Jupiter starts on November 30 and continues for 38 hours, examining Jupiter's upper atmosphere to determine proportions of hydrogen and helium there. Also the instrument will look for polar glows or auroras (See Table Four).

A second viewing period, beginning 9 hours before closest approach, lasts for five hours. But the early view may be most important because closeness to Jupiter may blind the instrument with too much radiation.

Infrared inspection begins 18 hours before closest approach to measure temperatures of first Callisto, then Ganymede, Europa, Io, and Amalthea. Starting 2 hours and 11 minutes before closest approach, the instrument takes temperature measurements of Jupiter itself, its prominent features including the Great Red Spot, and its dark hemisphere.

Starting on November 5 an instrument known as IPP (short for imaging photopolarimeter) inspects light reflected from Jupiter to determine the nature of the atmosphere above the clouds as well as the structure and composition of the cloud layers. This instrument also inspects the satellites. And it acts like a television camera to provide information that is used to make pictures of the planet and its satellites.

At around six hours before closest approach, Pioneer 10 enters the zone of hard radiation known as the radiation belts and starts charting this region to precisely define its hazards to spacecraft flying close by the giant planet.

Three hours before closest approach, the Great Red Spot is probed by a variety of scientific instruments to gain a better understanding of this mysterious region.

Closest approach is called periapsis. It takes place at 6.26 p.m. PST, on December 3 when Pioneer literally skims across the cloud tops at 82,000 miles an hour, perhaps even faster. Ten minutes afterward Pioneer passes through the equatorial plane and will encounter any dust belt that may be present there. An increase in dust concentration of up to 1000 times that in the interplanetary environment might occur, but hopefully not enough to damage the spacecraft.

TABLE 2. TIMES OF CROSSING SATELLITE ORBITS

SATELLITE	DATE	TIME	DISTANCE FROM JUPITER MILES
HADES	NOV. 8	2.26 A.M.	14,680,000
POSEIDON	8	10.26 A.M.	14,420,000
PAN	9	12.26 A.M.	13,840,000
ANDRASTA	11	10.26 A.M.	12,821,000
DEMETER	22	2.26 P.M.	7,231,000
HERA	22	2.26 A.M.	7,243,000
HESTIA	22	6.26 A.M.	7,085,000
CALLISTO	DEC. 2	12.26 P.M.	1,125,000
GANYMEDE	3	4.26 A.M.	496,400
EUROPA	3	10.26 A.M.	372,500
IO	3	2.26 P.M.	221,300
AMALTHEA	3	6.26 P.M.	

*PIONEER DOES NOT GET CLOSE ENOUGH TO JUPITER TO CROSS THIS ORBIT.

TABLE 3. SOME IMPORTANT EVENTS

DATE	TIME	EVENT
NOV. 24	6.26 P.M.	ENTER THE BOW SHOCK WAVE (EARLIEST)
28	6.26 P.M.	ENTER JUPITER'S MAGNETIC FIELD (EARLIEST)
DEC. 3	11.26 P.M.	ENTER CRITICAL REGION OF INTENSE RADIATION (RADIATION BELT)
	6.36 P.M.	CROSS EQUATORIAL ZONE WITH POSSIBLE DUST HAZARD
	6.41 P.M.	GO BEHIND IO (OCULTATION)
	7.42 P.M.	GO BEHIND JUPITER (OCULTATION)
	8.16 P.M.	ENTER INTO JUPITER'S SHADOW
4	12.26 A.M.	LEAVE HARD RADIATION BEHIND
19	—	LEAVE THE BOW SHOCK
JAN. 2	—	END OF ENCOUNTER SEQUENCE

TABLE 4. SOME EXPERIMENTS

DATE	TIME	EVENT
NOV. 30	2.26 P.M.	FIRST ULTRAVIOLET LOOK AT JUPITER
DEC. 2	7.05 A.M.	INFRARED LOOK AT CALLISTO
3	3.17 A.M.	INFRARED LOOK AT GANYMEDE
	8.40 A.M.	SECOND ULTRAVIOLET LOOK AT JUPITER
	11.08 A.M.	INFRARED LOOK AT EUROPA
	12.38 P.M.	INFRARED LOOK AT IO
	3.45 P.M.	LOOK AT THE GREAT RED SPOT
	4.18 P.M.	INFRARED INSPECTION OF JUPITER
	6.14 P.M.	INFRARED LOOK AT AMALTHEA

At 15 minutes after closest approach, the spacecraft passes behind Io. As it does so refraction effects bend and weaken the radio signals from the spacecraft and enable scientists to calculate what sort of an atmosphere Io possesses. It could be that an electrically charged atmosphere links up lines of force in Jupiter's magnetic field and causes enormous electrical discharges in Jupiter's atmosphere to generate powerful radio signals received on Earth from the planet. Pioneer should be able to check if this is true.

An hour after passage behind Io, the spacecraft goes behind Jupiter itself for 65 minutes. Similar bending and weakening of free electrons in Jupiter's ionosphere (electrified upper atmosphere) and something of the density and composition of Jupiter's atmosphere in general. These measurements are made as the spacecraft both goes behind and emerges from the bulk of Jupiter.

At 2 hours and 51 minutes after closest approach, Pioneer enters the awesome shadow of the huge planet and remains in darkness for 51 minutes. On returning into sunlight Pioneer starts to leave the environment of Jupiter and as it heads for the stars of the Galaxy it makes as many similar measurements of the Jovian system as when it came in. In the weeks following encounter the spacecraft continues to make measurements of the solar wind and of particles and magnetic fields in space. It will try to find out what effects Jupiter has on the interplanetary environment outside the big planet's orbit. There are several unanswered questions about space beyond Jupiter's orbit that Pioneer may throw light on. How many and what types of cosmic rays come into the Solar System from the Galaxy? What is the distribution of hydrogen and helium in space beyond Jupiter and where does it originate? Where is the boundary at which the solar wind stops blowing and in interstellar space—the space between the stars—really begins?

Communications may be maintained with Pioneer for five years, though the mission was designed for only several months encounter. As the communications distance becomes steadily longer, the incoming signals will become incredibly faint. But the link with Pioneer may last until it crosses the orbit of Uranus in 1979, then to be lost as the tiny emissary of mankind carries its message of an intelligent race on Earth into the cosmos.

THE PICTURES OF JUPITER AND ITS SATELLITES

Pictures of Jupiter could be disappointing. Scientists do not know how the equipment will stand up to the hostile environment of the mighty planet. But if all goes well the pictures may provide inspiring views of the big planet and its planet-sized moons.

Building up pictures of Jupiter and the satellites begins on November 5. Early images are

used to test the equipment—then, on November 26, the image-making sequence goes to a 23 hours-a-day basis. Forty-eight hours before closest approach, the pictures from Pioneer are expected to be better than any obtained from Earth with the largest telescopes. And by eight hours before encounter, the image of Jupiter fills the field of view of the picture making system.

There are plans for more than 300 views of Jupiter and ten of its satellites in the two weeks period, including some close-ups of satellites (see Table Five). As Pioneer flies around the night side of Jupiter, view angles impossible from Earth are obtained. If the imaging system withstands the passage through the radiation belts spectacular pictures of the close approach may reveal features 100 miles across, of cloud currents and eddies, and provide new information on features such as the Great Red Spot. These pictures will be made available to national television as soon as they have been processed by the computers at NASA's Ames Research Center.

WHAT TO LOOK OUT FOR

Television, radio and newspapers will start carrying reports on Pioneer's progress about a month before closest approach. As pictures and results flood back from the Jovian system, television will give the news quickly. A day later newspapers will carry more detailed reports. But for the complete story we have to wait for weeks or months until scientists can analyze the wealth of new information and write interpretive articles for magazines such as *Scientific American* and *Science News*. A few newspapers will also carry these detailed science stories, too.

PIONEER 11

From the results of Pioneer 10's flight past Jupiter, project engineers and scientists will

decide how Pioneer 11 should be directed for its encounter in December, 1974. If Pioneer 10 is damaged by the environment of Jupiter, particularly the radiation and possible dust belts, Pioneer 11 may be directed to fly by further out from the planet. But if Pioneer 10 emerges unscathed, Pioneer 11 might be sent even closer to further test the radiation belts.

STUDY PROJECTS

ONE

Take the various events listed in Tables 1 through 5 and make a combined listing of the sequential happenings when Pioneer 10 flies through the Jovian system. List the date, time, what happens, and leave a column for remarks about each event.

TWO

Use the list you have made during the encounter. Watch TV, listen to radio, and read the newspapers to check each event as it is reported. Fill in remarks as to what is discovered. Use this information to check your study projects made in connection with earlier leaflets of this series. Check your drawing or painting of Jupiter (leaflet #2) to see if you guessed right what the planet looks like. Also check and correct your "unknowns" list of leaflet #3.

READING LIST

Watch TV newscasts and special programs.
Listen to radio newscasts.
Read your local newspaper or national news-magazines.

TABLE 5. PHOTOGRAPHS (IMAGES) OF JOVIAN OBJECTS

DATE	APPROXIMATE NUMBER OF PICTURES	OBJECT
NOV. 26	12	JUPITER
27	26	JUPITER
29	25	JUPITER
30	20	JUPITER
DEC. 1	26	JUPITER
	2	IO
2	23	JUPITER
	2	IO
	2	CALLISTO
	2	GANYMEDE
3	18	JUPITER
	1	IO
	1	EUROPA
4	23	CRESCENT-SHAPED JUPITER
5	22	JUPITER
6	16	JUPITER
7	31	JUPITER
8	25	JUPITER
9	38	JUPITER
10	20	JUPITER